EETF Quarterly Progress Report

Grant # 7310029

Safe and Efficient Exhaust Thimble

Submitted by:

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Period: July 1, 2013 – September 30, 2013 (Q3)

Summary

The project Budget/Milestone Schedule from the Grantee's original scope of work is shown below. No changes to this scope have been made or requested.

Milestone	Task		Start Date	End Date	Grant Funds	Match Funds	Total Budget	Deliverables
	1	Purchase and assembly of DAQ and instrumentation	Feb 2013	Feb 2013	$12,196		$12,196	DAQ system "dry-run" data set to ACEP for plan verification
	2	High fidelity performance test of 2-inch thimble	Mar 2013	Mar 2013	$11,193	$5793	$16,986	Performance test results
MS 1: AEA accepts performance test results								
	3	Design, construct and testing of 4, 6, 8, and 10-inch thimbles	Apr 2013	Oct 2013	$62,868		$62,868	Performance test results
	4	Draft project report	Nov 2013	Dec 2013	$816		$816	Draft project report
	5	Final project report	Dec 2013	Jan 2014	$816		$816	Final project report
MS 2: AEA accepts final report								
Total					$87889	$5793	$93,682	

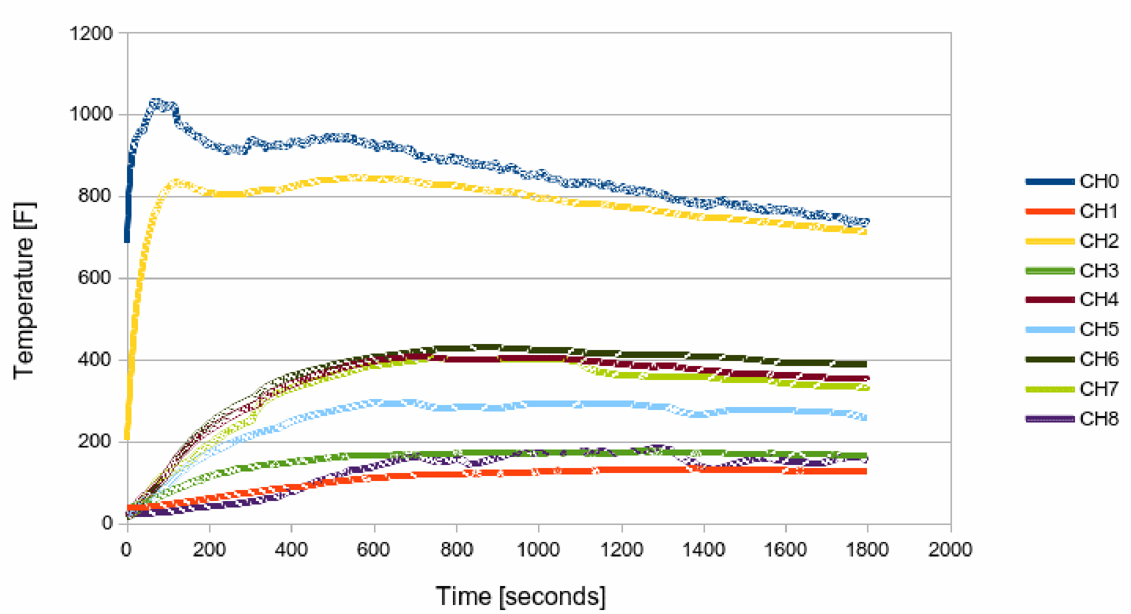

Figure 1: Temperature Data

Deliverables Submitted

Task 1 is completed and milestone 1, DAQ system "dry-run" data collection and verification; was completed during this quarter. An example of temperature data collection for a single experiment is shown in Figure 1 above. Th schematic in Figure 2 shows the location of the temperature sensors (thermocouples) on the thimble and adjacent building materials. Air velocity is measured at the inlet.

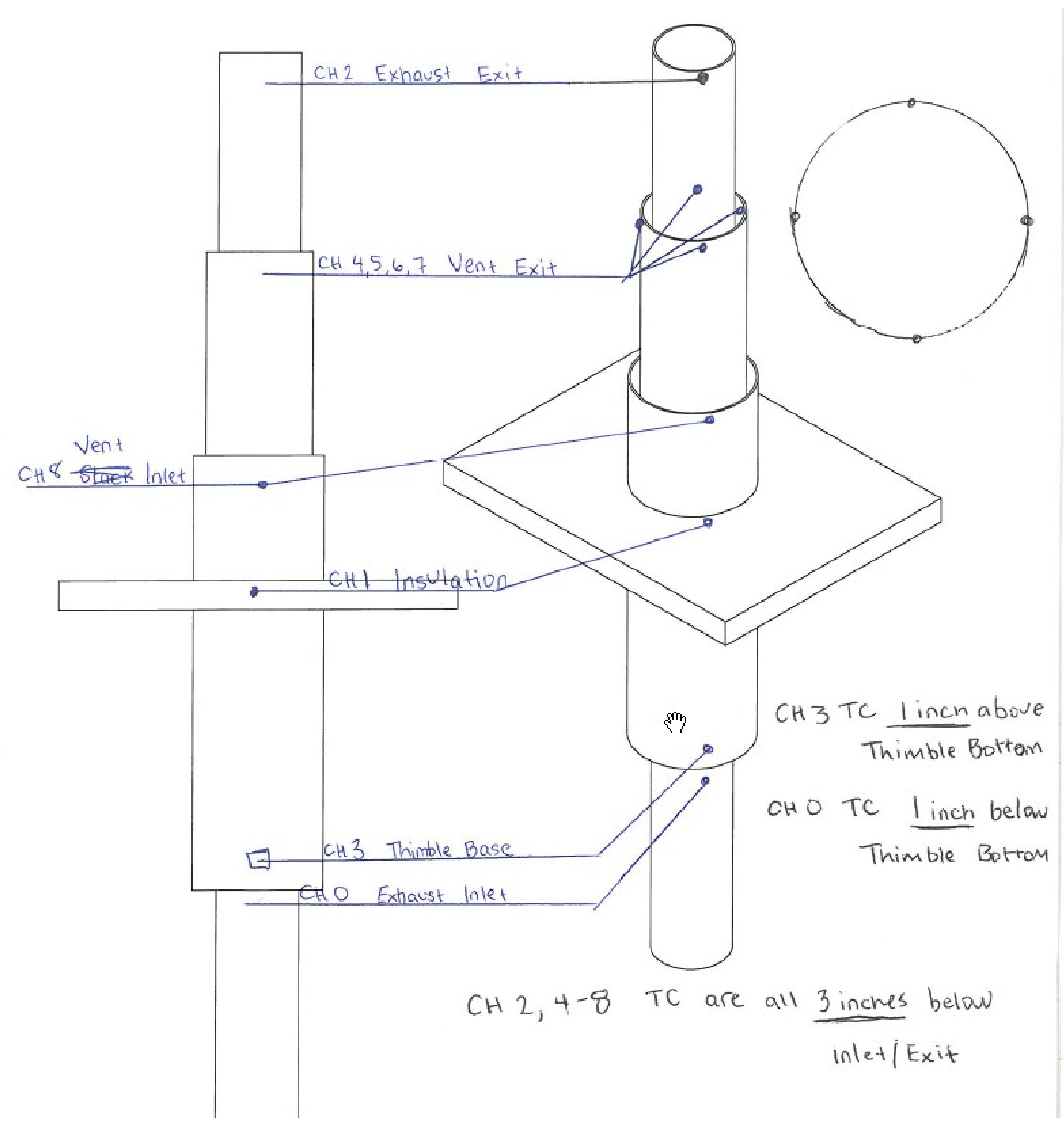

Figure 2: thermocouple locations on the thimble

Budget

Total funds expended to date are $6477.34 of the grant total $87,889.00 (~7.5%). Primary expenditures during this quarter are personnel services (salary) during continued work on task 2. The project is currently running at 26% of projected budget in terms of percent completion of each task at this point.

Schedule Status

Task 1 is complete, and Task 2 is behind the original schedule. The original plan was for several members of the initial project team to perform the experiments. However, scheduling the experiments within other career obligations has been difficult. To address this, two students have been recruited to assist with the experiments and are supervised by the main project PI. This caused a delay as the students were brought up to speed, but it is anticipated that things will progress more quickly now that they are trained. This change in personnel is also reflected in the under-budget thus far for the project.

Percent Complete

The estimated percent completion of the 5 project tasks is shown in the table below.

Task 1: 100%	Task 2: 75%	Task 3: 0%	Task 4: 0%	Task 5: 0%

Task 1, *Purchase and assembly of DAQ and instrumentation*, is complete. This task was under budget because several pieces of equipment were obtained through surplus from previous university projects. This includes the data collection computer, A/D hardware box from National Instruments, and several non-grounded thermocouples.

Task 2, *High fidelity performance test of thimble*, is about 75% complete. Reproducible temperature data are being collected from 9 different locations on the thimble, and 18 additional experiments has been conducted since the Q2 progress report. As figure 2 above shows, there are several "redundant" recordings at the vent outlet. These were installed when it was observed that there appeared to be temperature variations around the circumference of the outlet. Much time and several of the experiments performed during this review period were done in order to determine whether these are true temperature differences or a problem with the sensors or A/D system. The temperature variations are consistent between experiments, and all the sensors were re-calibrated in both a hot-sand bath and ice/boiling water set points. Therefore, it appears this variation is "real", and the product of higher-order phenomena in the flow pattern within the thimble.

Although the remaining tasks are still behind schedule, it is anticipated that the experiments will begin to progress more quickly for two reasons. First, the experimental protocol has been significantly solidified, and the students are becoming more efficient. Second, both students are currently working in addition to their course load, but plan on working over the semester break and will have more time in the coming quarter. Alhtough task 3 is the bulk of the work, it may not not necessarily require the bulk of the time.

Work Progress

Since experimental data on the first thimble is reasonably consistent, they are being compared to a numerical heat and fluid flow model for corroboration. The numerical model will be used for size and material optimization after it is corroborated. The two main temperature locations being used for verification are (1) the thimble base where it attaches to the building ceiling/roof, and (2) the exit vent temperature which convects the heat away.

The figures below illustrate some of the model predictions thus far. Figure 3 shows the flow velocity at the base of the thimble where flow reverses. The model is axi-symetric, and the left-hand side is the hot interior of the exhaust. Flow is advected upward by bouyancy forces.

Figure 4 shows the temperature variation within the thimble at the base. The hot interior (red ~ 1000°F, blue ~80°F). The channel width is 1-inch, so the thermal boundary layer is less than 1/4 inch and grows at the flow approaches the top of the thimble.

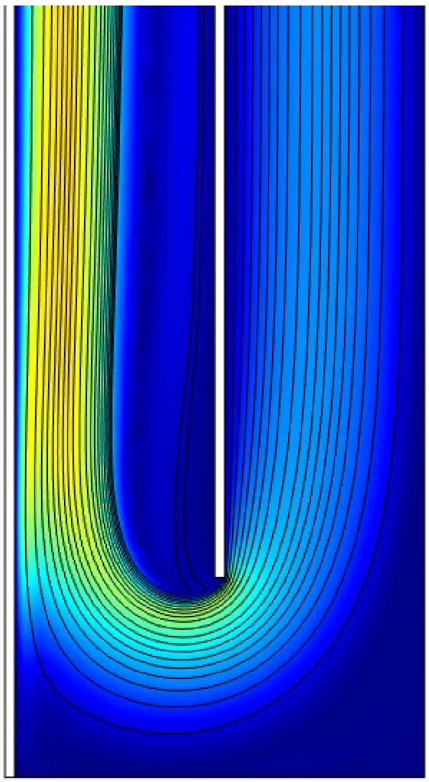

Figure 3: Flow velocity and stream lines at the thimble base

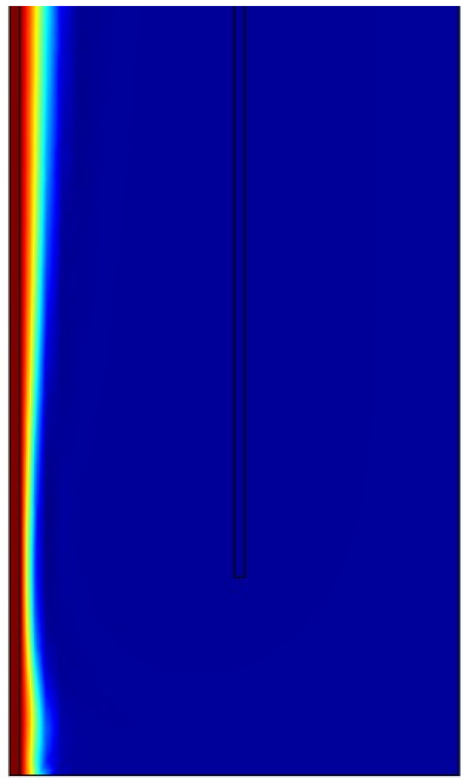

Figure 4: Temperature distribution at the thimble base

The figures below illustrate the temperature and flow at the thimble outlet. Figure 5 shows the air temperature at the thimble outlet. The increase in the thermal boundary layer is apparent here where it has grown to about one-half of the channel width. Flow is forced out (to the right) by the angled rain cap (this is not shown in figure 2, but prevents rain water from accumulating inside the thimble). Figure 6 shows the temperature across this outlet (top to bottom) at several times during the experiment. Steady-state is approximately reached, so most lines lie on top of each other. The top temperature is approximately 850°F (red in figure 5) and the bottom about 150°F (blue in figure 5).
The two figures are approximately vertically aligned as shown on the following page to assist in the interpretation. The model is predicting a large (~700°F) temperature differential across the outlet. However, the cup-mixing average is 500°F, which agrees fairly well with the ~400°F recorded by the sensors at the outlet of the thimble (see Figure 1). This is a reasonable interpretation since the air flow likely becomes turbulent as it exits and does not maintain the laminar distribution shown in the model.

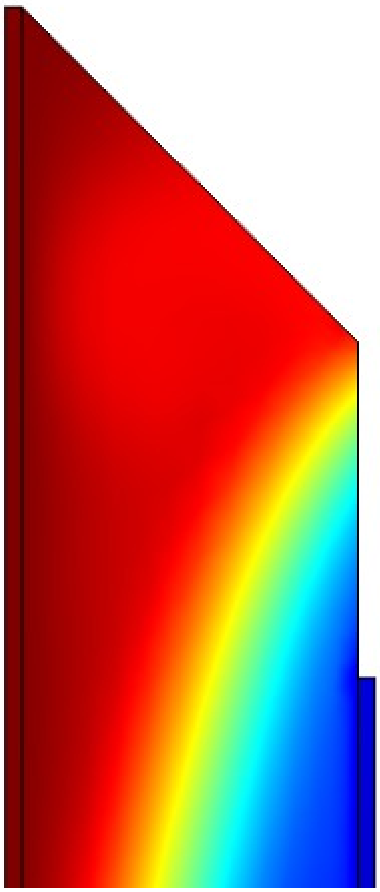

Figure 5: Temperature distribution at thimble vent outlet

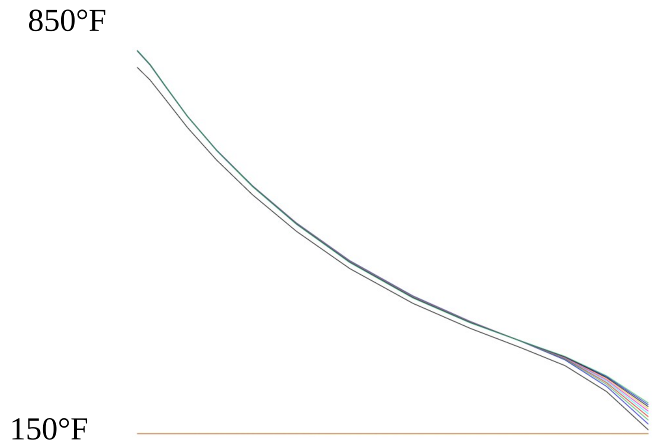

Figure 6: Temperature along the outlet.

Future Work

The next quarter future work, and expected outcomes, are the following in sequential order:

- Complete task 2 experiments.
- Construct the next size thimble (4-inch diameter) and install.
- Test 4-inch thimble according to the current protocol.
- Adjust numerical model to 4-inch diameter and compare with experimental data.
- Construct, install, and test 10-inch thimble.